ESTIMATING LOGGING DRAFT[1]

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Measurements of draft as tension (pounds-force, lbf) in the towing chain were made while drawing logs over a range of tractive surfaces. An average draft varied from 4% of the weight of the load for a wagon with pneumatic tires on a gravel road to 57% when using logging tongs in snow. This information can help the teamster match a load with the power available and establish realistic guidelines for animal performance.

INTRODUCTION

Most teamsters enjoy working in a wood lot. Logging provides firewood for the teamster, exercise for the team, and logging is a great activity for training draft animals as they maneuver loads in a wide range of conditions. Estimating logging draft requires a knowledge of the weight of logs and an understanding of how logging tools and implements can influence draft.

Logs are heavier than they appear. A freshly cut hickory log 12 feet in length and 18 inches in diameter weighs about 1,500 lbs.

Oxen are well suited for drawing heavy loads over rough and uneven ground.

The draft load that the team feels as tension in the towing chain varies with the implement or tools used and the tractive surface over which the logs are drawn. It is not widely understood how the selection of logging tools and implements can influence draft.

This article reports on research done at Tillers' training center to compare logging draft using common tools and implements over bare and snow-covered ground. Specific objectives were to measure an average draft and develop rules-of-thumb for estimating logging draft using: 1) logging tongs, 2) a go-devil, 3) a logging arch, 4) a wagon with pneumatic tires, and 5) a wagon with steel tires.

TIMBER DENSITY

Timber varies in density (lb/ft^3) based on wood species and moisture content. Freshly cut timber contains considerable moisture and can weight twice as much when fresh as when air-dry (<20% moisture). Typical densities for several species of timber common throughout the Northeast and upper Midwest are provided in Table 1. Since uncut logs dry slowly the green density is generally most representative of recently sawn or down timber.

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Table 1. Typical densities of green and air-dry timber.

Wood	Density, lb/ft^3	
	Green	Air-Dry
Beech	54	46
Cherry	46	36
Cottonwood	60	29
Elm	56	36
Hickory	70	54
Sugar Maple	58	46
Red Oak	63	46
White Oak	61	49
Red Pine	34	33

Based on: Forest Products Laboratory. *Wood Handbook: Wood as an Engineering Material*. Agric. Handbook 72. Washington DC:USDA; rev. 1987.

DRAFT MEASUREMENTS

Draft is a measure of a load's resistance to movement. Draft is the force (pounds-force, lbf) needed to move an object in the direction of travel. A convenient rule-of-thumb for estimating the pulling ability of oxen is that a well-conditioned team can provide an effort measured as tension (lbf) in the draft chain equal to 10-12% of their body weight throughout the day. This level of loading allows a reserve of power to overcome normal variations in draft and provides for a sustained effort within environmental constraints. On the farm and in the forest working teams routinely pull much more than 10-12% of their weight for short periods of time.

Tillers' draft measurements were made using a simple hydraulic pull meter--a closed-circuit fluid system that consisted of a hydraulic cylinder and a pressure gauge. The pull meter was placed in the towing chain and the reaction force was measured by the pressure gauge on the discharge side of the cylinder. This device allowed instantaneous measurements of draft (lbf), and when combined with time and distance, power output (hp). Tillers' 3,850 lb team of oxen, Lewis and Clark, were used to pull the loads.

SKIDDING ON SNOW-COVERED GROUND

Logging has long been a winter activity for farmers in the upper Midwest and Northeast. In winter logging does not conflict with other farming operations and insects are not a problem. Frozen and snow-covered ground may aid in the movement of heavy loads over uneven terrain. While many implements are available for transporting logs, we tested two in mid-February on snow-covered ground: 1) logging tongs, and 2) a go-

Our Need to Know . . .

In writing this series of articles on implement draft, we at ***Tillers International*** are seeking to improve the relationship of people with their working animals. We are committed to easing the burden of animals as they help meet the energy needs of small farms.

If we lack an understanding of what we ask of our animals, we have limited means of knowing why they may act up in particular ways. If a teamster mistakenly thinks a load is light, he or she may become overly demanding. Underestimating a load may lead to a heavy whip and frustrate the animals into becoming nervous and unpredictable. Repeatedly overloading a team will discourage them and reduce their willingness to pull. Our goal is to enhance the teamsters ability to match the ability of the team with the demand of the load.

Calculating a load will take a little practice and attention. But you will be rewarded with a more productive relationship with your animals. They trust us to attend to such details and their trust grows as we demonstrate our trustworthiness to them. Those who have not worked oxen or draft horses may think this overestimates their perceptiveness and memory; nonetheless, experience clearly teaches the perceptive teamster that oxen and horses develop differing levels of trust and respect for variations among drivers. There are real benefits to be gained by understanding the loads you are asking your animals to move. We hope this article will help all teamsters empathize with the tasks they are presenting to their animals.

devil, also known as a logging lizard.

Logging tongs are a simple device used to grasp the log and hold it fast in skidding over the ground. Tongs are often used in skidding logs a short distance to a staging area for loading on a wagon or sled. Tongs are a quick-hitch option compared to wrapping a chain around the circumference of the log.

Logging tongs grasp the log for skidding.

How heavy is that log?

Logs vary according to size, species and moisture content. In order to calculate the weight of a log, first calculate it's volume (ft^3) and then multiply the volume by the density (lb/ft^3, from Table 1).

Example: Estimate the weight of a freshly cut hickory log measuring 12 ft long and 18 inches in diameter.

Weight (lb) = vol (ft^3) * density (lb/ft^3)

Vol (ft^3)= 3.14 * rad^2 (ft) * length (ft)

The radius is one-half of the diameter.

Radius (ft) = 9 in.÷12 in. per ft = .75 ft

Vol = 3.14 * (.75)^2 ft * 12 ft

Vol = 3.14 * .56 ft^2 * 12 ft

Volume = 21.2 ft^3

Log weight is volume (ft^3) multiplied by the density (lb/ft^3) of freshly cut (green) hickory

Weight (lb) = 21.2 ft^3 * 70 lb/ft^3

Weight = 1,484 lb

A go-devil consists of two angled skids and an elevated platform to carry the hitch end of the log. The angled skids allow the go-devil to deflect off stumps and other obstructions. Elevating the hitch end of the log reduces ground contact, friction and motion resistance, prevents the butt of the log from catching on roots or stumps, and helps keep the log clean.

When using the logging tongs to skid a 1,475 lb oak log, we used a beveled cut on the leading edge of the log to help keep it from catching on roots and other obstructions. The snow cover was three to five inches and well settled, and the ground was frozen and level. An average draft was 845 lbf, 57% of the weight of the log. Considerable effort was needed to pull the log as tension in the towing chain was 22% of the team's body weight. Power delivery was 4.3 hp (Table 2).

Table 2. Logging draft and power delivery when drawing a 1,475 lb oak log.

	Draft				
	lbf	% Load	% BW	mph	hp
Go-devil					
Hardpack	284	19	7	3.4	2.6
Snow	724	49	19	2.1	4.1
Logging arch					
Gravel road	590	40	15	2.2	3.5
Hay ground	592	40	15	2.1	3.3
Logging tongs					
Hay ground	806	55	21	2.1	4.5
Snow	845	57	22	1.9	4.3

Elevating the hitch end of the log on a go-devil reduced ground contact, friction, and motion resistance. An average draft was 724 lbf, a 14% reduction compared to using the tongs. Draft as tension in the towing chain was 49% of the weight of the load, an effort equal to 19% of the body weight of the team.

We also used the go-devil to draw the log over a hard-pack snow surface. This was packed snow over a gravel road, not quite as hard as ice but much harder than the settled snow cover in the field and wood lot. An average draft was 284 lbf. Tension in the

towing chain was equal to 19% of the weight of the log, 7% of the team's body weight. Draft increased 155% in going from the hard-packed snow on the road to the settled snow in the field. It is no wonder why loggers were willing to spend considerable time and effort in packing and icing down winter logging trails.

SKIDDING ON BARE GROUND

In late April we measured draft using logging tongs on bare alfalfa-grass hay ground. We also used a logging arch to draw

A go-devil elevates the hitch end of the log.

the 1,475 lb log over hay ground and a gravel road.

A logging arch is a wheeled implement with a raised hitch point that allows the arch to straddle the log and raise the hitch end of the log off the ground for transport. Raising the hitch end of the log reduces ground contact, friction, and motion resistance. This reduces draft, keeps the log cleaner than when ground skidding and reduces rutting and ground disturbance.

The logging arch we used was built by Fred Herr, a local horse logger. The arch weighed about 750 lb, the hitch point was 26 inches above the axle, and the tongue weight was 90 lb. Logging tongs were used to grasp the hitch end of the log for transport. Under load, the tongue weight came off the yoke as it counter-balanced the rearward torque of the log.

Fred Herr's logging arch.

When drawing the log with the logging arch there was little difference in draft when traveling on a gravel road or on alfalfa-grass hay ground. An average draft was 592 lbf on the gravel road and 590 lbf on the hay ground. This includes the draft of the arch plus the log. Draft as tension in the towing chain was 40% of the weight of the log. This was a draft load equal to 15% of the team's body weight.

We also used the tongs to draw the log over an alfalfa-grass sod. The ground was firm but moist. Tension in the towing chain was 806 lbf, a draft load equal to 55% of the weight of the load and 21% of the team's body weight. Surprisingly, draft in the snow (846 lbf) was about 5% higher than on bare hay ground. The sod likely provided more friction per unit area, but the log sank in the snow and contacted a much larger area. Even though we made a beveled cut on the butt of the log, it still plowed and compressed snow in cutting a path. Motion resistance was greater in the snow than on the hay sod.

In comparing draft on the hay sod when using the logging arch (590 lbf) with draft when using the tongs (806 lbf), it appears that one could increase the weight (lb) of the load by 36% when using an arch and achieve the same draft load (lbf) as when using tongs with the smaller load. This increased productivity by one-third with no additional effort required of the team.

WAGON TRANSPORT

Logs are often hauled a short distance to a

staging area and then loaded on a wagon for transport. Draft for wagons and carts on level ground is largely the force needed to overcome the rolling resistance of transport wheels. Rolling resistance is the force needed to keep an implement moving at a constant speed while compressing or moving soil and overcoming wheel and axle-bearing friction. Rolling resistance will increase considerably when going from a hard surface to soft or tilled soil.

Wagon and implement draft also increase when pulled up a slope. A slope is often described as a percentage and is calculated as the ratio of rise to run. A 10% slope indicates a one foot vertical rise per ten feet of horizontal run. Over a 10% slope you vertically lift 10% of the load one foot for every ten feet of linear pull. You can estimate draft by adding 10% of the weight of the load (lb) to the draft (lbf) expected on level ground. For a 20% slope, add 20% of the load. This is a suitable estimator for predicting draft on the moderate slopes frequently encountered.

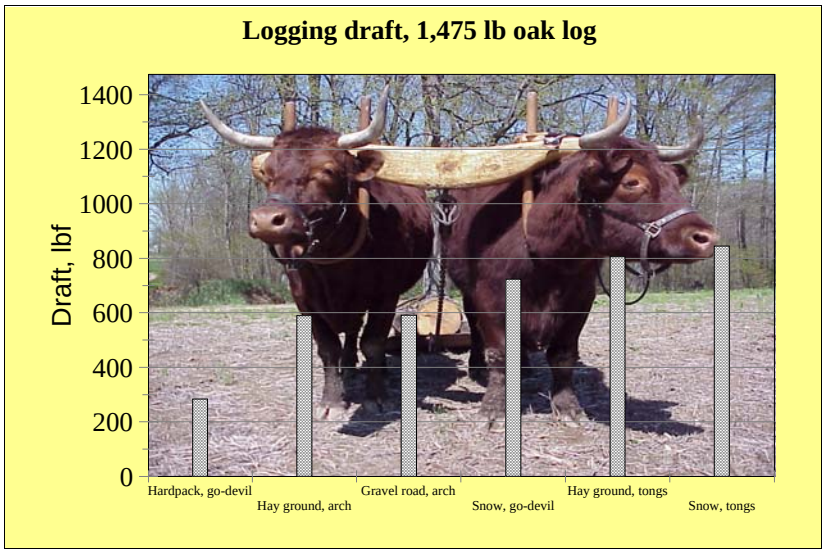
Compared to steel tires, pneumatic tires cushion the impact of stones and other obstructions. This is particularly helpful on a hard surface such as a gravel road. Pneumatic tires also deflect under a load. As the load increases, tire deflection increases the tire/soil contact area. This provides a larger bearing surface, improves flotation, reduces tire sinkage and reduces rolling resistance.

Table 3. Representative draft per 1000 lb GVW for a range of skidding and transport methods.

	Draft, lbf	
	per 1000 lb GVW	% of GVW
Wagon, pneumatic tires [1]		
Gravel road	42	4
Hay field	70	7
Firm ground	101	10
Wagon, steel tires [2]		
Gravel road	91	9
Hay field	125	13
Firm ground	158	16
Go-devil		
Hardpack snow	193	19
Snow, settled	491	49
Logging arch [3]		
Hay field	400	40
Gravel road	401	40
Logging tongs		
Hay field	546	55
Snow, settled	573	57

[1] 6.00-16 bias ply tires inflated to 30 psi.
[2] Steel tires 4 inches wide, 24 inches in diameter (front), 4X28 (rear).
[3] GVW based only on the weight of the log.

In Tillers' wagon draft trials an average draft using pneumatic tires ranged from about 4% to 10% of gross vehicle weight (GVW, the weight of the wagon plus the load). When using steel tires draft ranged from 9% to 16% of GVW. Logging draft results are listed in Table 3. The data are presented as a representative draft per 1000 lb of gross vehicle weight. Presenting the draft requirements in such a way allows convenient application of the data to wagon and implement loads of various size. These logging draft measurements can be used as guidelines in matching a load with the power available.



Example 1: In training a young team, a teamster seeks to limit an average draft measured as tension in the draft chain to 300 lbf. Logs will be hauled across a level snow surface using a go-devil. Estimate the weight of the largest log allowable.

Solution: Referring to Table 3, about 49% of the weight of the load is transferred to the team as tension in the towing chain when using a go-devil on a level, snow-covered surface. 300 lbf ÷ .49 equals 612 lb.

The largest allowable log is about 600 lb.

Example 2: Estimate draft when using a go-devil to draw a 600 lb log up a 15% slope over a snow-covered surface.

Solution: Total draft is the sum of a motion resistance due to ground friction and the lifting of the load up the slope. Referring to Table 3, about 49% of the weight of the load is transferred to the team as tension in the towing chain when using a go-devil on level, snow covered ground.

600 lb * .49 = 294 lb.

Uphill draft increases at a rate proportional to the slope and weight of the load.

600 lb * .15 = 90 lb.

Total draft is 294 lb + 90 lb = 384 lb.

Example 3: Compare draft for an 1,800 lb log when using logging tongs and a logging arch. The log will be hauled across a level, firm sod.

Solution: Referring to Table 3, about 40% of the weight of the load is transferred to the team as tension in the towing chain when using a logging arch, 55% when using logging tongs.

1,800 lb * .40 = 720 lbf (logging arch)

1,800 lb * .55 = 990 lbf (logging tongs)

SUMMARY

We at *Tillers International* are committed to easing the burden of animals as they help meet the energy needs of small farms. In order to improve our understanding of the effort needed in logging, measurements of draft as tension in the towing chain were made while drawing logs over a range of tractive surfaces. An average draft varied from 4% of the weight of the load for a wagon with pneumatic tires on a gravel road to 57% when using logging tongs in snow. This information can help the teamster match a load with the power available and establish realistic guidelines for animal performance.

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